DSN Command System Mark III-78

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The DSN Command System Mark III-78 data processing includes a capability for a data handling method called "store-and-forward." A description of the data processing for command store-and-forward is contained in this article.

I. Introduction

The last DSN Progress Report article discussing the DSN Command System (Volume 42-35) defined the implementation that was in process for the Mark III-77 configuration. The prime implementation was to occur at the Deep Space Stations and at JPL in the Ground Communication Facility (GCF) Central Communications Terminal. At the Deep Space Stations, new minicomputers replaced the existing obsolete computers. Presently, all stations have been upgraded to the Mark III-77 configuration, except DSS 11 at Goldstone, California. In the Central Communication Terminal (CCT), minicomputers were implemented such that automatic data routing (instead of manual line patching) of the high-speed data line traffic could be accomplished. The computers in the CCT have been installed, and the final phases of software testing are in process. As soon as the new minicomputers at DSS 11 are implemented (March 1978) the DSN Command System Mark III-77 configuration will be complete. Due to the fact that this hardware reconfiguration occurred over a 15-month time interval (station-by-station), the command data processing capabilities in the new minicomputers had to be "held" to the level of capabilities that existed in the computers being replaced. That is, the data interfaces with the Mission Operations Control Centers had to be maintained such that those centers could interface with either a Mark III-75 or Mark III-77 configured DSS. Now that all stations (DSS 11 is imminent) have significantly increased command data storage capability, plans are to significantly change the data processing capabilities of the DSN Command System Mark III-78.

The data processing capabilities of the DSN Command System have remained constant since late 1973. The interface with the Mission Control Centers (at JPL and at Ames Research Center) have likewise remained constant. These capabilities have supported Helios, Mariner Venus-Mercury, Pioneers 10 and 11, Viking and Voyager missions. The design of the data processing capabilities was based on the "worst case" mission needs while recognizing the limited command storage capabilities at a DSS.

The types of missions supported, coupled with the constraint of limited command storage at a Deep Space Station dictated a system data processing design in which commands are "held" at the Mission Control Center and "fed" to a Deep Space Station in small quantities. These small quantities of commands are temporarily held at a Deep Space Station prior to radiation to the spacecraft. The data processing capabilities, especially with regard to the data interface with the Mission Control Centers, are complex and highly interactive. This is primarily due to providing the capability for Mission Control to change a command sequence in real-time. The commands temporarily stored at a DSS can be "reshuffled" when a command sequence is changed. This requires numerous software algorithms to ensure the validity of a "new" command sequence.

Due to the nature of recent missions and spacecraft supported by the DSN, the data processing requirements are changing. The natures of the missions are relatively long lasting; thus new data processing capabilities are necessary to minimize operations personnel (costs) that are dedicated to operating and monitoring the Ground Command System. The more recent spacecraft being supported (e.g., Viking, Voyager and the yet to be launched Pioneer Venus) have onboard command storage and sequencing capabilities. Further, the operation of these spacecraft is based on loading this onboard storage well in advance of action to be taken by the spacecraft. That is, very few "direct action" commands are being used now for spacecraft support. Ground Command System data processing capabilities are now being developed which are more compatible with future mission operations and spacecraft concepts. The description of this DSN portion of the Command System data processing is the subject of this article.

II. General Concept – Command Store-and-Forward

The end-to-end command data flow is shown in Fig. 1. Each element of the "system" is responsible to temporarily store, then forward a specific set of spacecraft commands. This method of data delivery has been termed "store-and-forward." At the Mission Operation Center, as part of mission-dependent capabilities, a "set" of commands is generated based upon the particular requirements for a series of mission objectives for a given period of time. These commands are usually computer-generated and are normally generated on the order of days in advance of actual execution by the spacecraft. After generation, the set of commands is then stored for later entry into the real-time ground command system. Entry for temporary storage into the Mission Operation Center real-time command system normally occurs on the order of hours before delivery to the DSN. When a Deep Space Station has been scheduled to track a given spacecraft, it is available for the command function. The station will receive the set of commands from the Mission Control Center via a high-speed data line. This set of commands will normally be received the first few minutes of the stations track. The set of commands is then available for radiation to the spacecraft. At the option of the Mission Operations Team, radiation can begin immediately, or a few hours into the track. Upon receipt by the spacecraft, the commands are stored, normally in an onboard computer, for later execution. As can be seen from the above description, each element in the system receives and stores the complete set of commands prior to forwarding: thus the term store-and-forward. This article discusses the DSN data processing portion of this end-to-end command store-and-forward method of data handling.

III. DSN Data Processing, Command Store-and-Forward

The DSN data processing can best be described by defining three distinct functions that occur to command a spacecraft:

(1) Receiving and storing the command data at a DSS.

(2) Queuing command data to be radiated to the spacecraft.

(3) Radiating the command data to the spacecraft.

Before discussing the above three functions, command files and file elements need to be defined. The data handling design is based upon blocking the command data into files made up of file elements.

A. Command Files

The basic "set" of spacecraft commands that is forwarded from one ground system element to the next is a command file. Generally, multiple files will be generated for forwarding. Every file is composed of two element (1 element = 1 high-speed data block) types. The general structure is:

Header element	0
Command element	1
Command element	2
⋮	
Command element	n

The header element contains file identification information, file processing instruction, and a file checksum for error protection. The file identification information consists of a file time ID, a file text name, and a project reference number. Once generated (normally by project command generation software), the information is unchanged throughout the ground system. The file processing instructions consists of optional file radiation open and close window times, and an optional file bit 1 radiation time. File open and close window times specify the only time interval during which command elements in the file may begin radiation (i.e., a mission sequence may demand that specific commands *not* be sent before or after certain times). The bit 1 radiation time allows the project to specify the exact time at which the file is to begin radiation to the spacecraft. The file checksum is intended to provide error protection for the end-to-end ground command system. It is created at the time of file generation and is passed intact to the DSS. It adds reliability to insure that no data were dropped or altered in the transfer from one facility to another.

The command elements contain the actual command bits to be radiated to the spacecraft, identification information, and

processing-control information. The identification information includes the file time ID and file text name (same as the header element), project reference number, and element number (1-256). The processing-control information consists of an optional delay time. If the project wants to delay radiation of a command element (delay from the previous command), this delay time would be used.

The allocated storage for each file is of fixed length (256 elements). However, a file may not occupy all the storage allocated for it. For a given mission, 8 files can be stored at a DSS. Each command element can contain up to 800 spacecraft command bits. The total storage is thus greater than 1.6 million command bits – far in excess of any currently known spacecraft storage plans.

The data processing of the DSN Command System is based upon the data handling of the above-described command files and file elements.

B. Receiving and Storing Command Data at a DSS

As previously stated, the file(s) or set of commands to be radiated to the spacecraft are sent to a DSS during the first few minutes of a spacecraft track (i.e., just after spacecraft downlink signal acquisition). The first step in receiving and storing command data at a DSS is the process of opening a file area on the Command Processor Assembly (CPA) disk at a DSS. This is accomplished by the Mission Control Center sending a file header element to the DSS CPA. The CPA acknowledges receipt of this "open" instruction. The Mission Control Center immediately sends the command elements (up to 255) at near the high-speed data line maximum rate (maximum rate – 7200 bits/sec). The Mission Control Center then follows with a file "close" instruction. The DSS CPA again acknowledges the "close" instruction indicating file loading successful or unsuccessful. If successful, the Mission Control Center proceeds to send any remaining files (up to 8 total). If unsuccessful, the CPA specifies (in the acknowledge to the Mission Control Center) the reason for the failure and from what point in the file the command elements are to be retransmitted.

There are numerous reasons the CPA rejects the "close" instruction, but the prime one would be an error occurring in the transmission link between the Mission Control Center and the DSS. The Mission Control Center retransmits the data and again attempts to "close" the file. Again, after a successful file close, the Mission Control Center proceeds to send any remaining files. Upon successful "closing" of all files, the loading and storing process is complete. This process will normally take less than 10 minutes to complete. The command data is then available for radiation to the spacecraft.

C. Queuing the Command Data for Radiation

After having loaded the file(s) at the CPA, files may be selected for radiation to the spacecraft. This process is called "attaching." A five-entry queue of file names is provided. The Mission Control Team determines in which order the files are to be attached, normally in the order in which they were sent to a DSS. The order in which they are attached determines the sequence in which they will be radiated: that is, first attached, first to radiate to the spacecraft. Attaching a file to the queue is accomplished by the Mission Control Center sending an "attach" directive to the DSS CPA. Each file, as it is attached, is placed at the bottom of the queue. After attaching the files, the top file in the queue is eligible for radiation to the spacecraft.

D. Command Radiation to the Spacecraft

The first command element in the top (prime) file in the queue begins radiation to the spacecraft immediately after attachment or as soon as all optional file instructions are satisfied. As previously stated, a file can have optional instructions – Bit 1 radiation time and file open and close window times. If used, these instructions control when the first command element in the file begins radiation to the spacecraft. The file is defined to be active when the first command element begins radiation. Upon completion of radiation of the first command element, the CPA radiates the second command element either immediately or when the optional instruction "delay" time has been satisfied. The CPA continues to radiate all command elements in the file until complete. After the first file completes the radiation process, the second file in the queue automatically becomes the prime file and the file radiation process is repeated. After the second file completes radiation, the third file becomes prime, etc. This process is repeated until all files in the queue are exhausted. The Mission Control Center can attach new files to the queue whenever space becomes available (i.e., after the first file radiates).

As the radiation of command elements in a file is in process, periodic reporting via high-speed data line messages to the Mission Control Center is accomplished. Transmission of these messages to the Mission Control Center occurs every three minutes, or after five elements have been radiated, whichever occurs first.

E. Additional Data Processing

The functions of (1) storing the command files at a DSS, (2) attaching the files to the queue and, (3) radiation of the commands to the spacecraft are rather straightforward and the above descriptions assumed nominal-standard operation of the data processing functions. However, the complexity of the

total data processing capabilities is a result of assuming worst case, failure-recovery, or non-nominal operating conditions. Numerous data processing capabilities exist to accommodate these conditions. Below is a list of the optional or non-nominal data processing functions.

1. File erase. The capability exists to delete a file from storage at the DSS CPA. This erase function can be accomplished either locally at a DSS or via high-speed data message from the Mission Control Center. It is expected that files will be stored on disk at the CPA that are not intended to be radiated to the spacecraft. Examples: Test files left from pretrack testing or the Mission Control Center sends wrong files to DSS. The file "erase" function is provided so that unnecessary files stored at the DSS can be deleted to make room for files intended for radiation to the spacecraft.

2. Clearing the queue. Files could be attached to the queue out of order. As previously stated, the order of file radiation to the spacecraft is dependent on the order of files in the queue. The queue can be cleared by a high-speed data message from the Mission Control Center.

3. Suspend radiation. If for some reason, Mission Control desires to stop command radiation, a "suspend" message can be sent from the Mission Control Center. This message stops command radiation to the spacecraft. The file is defined as being in the suspended state.

4. Command abort. As each command bit is radiated to the spacecraft, numerous checks are made to insure validity of the command data. If a failure is detected during radiation, the command element is aborted. Optional methods of treating an abort are provided. Automatic recovery can be attempted (resend the command element) or radiation is terminated until operator intervention occurs. If radiation ceases, again the file is said to be suspended.

5. Resume command radiation. To resume radiation of a suspended file (either suspended intentionally or from an abort) a message can be sent from the Mission Control Center to resume radiation at a specific element in the file.

6. Close window time override. The close window time (previously discussed) can cause an actively radiating file to become suspended. If this occurs, Mission Control can send a message to the DSS CPA to "override" this time. The close window time override directs the CPA to ignore the close window time and proceed as if it were infinity.

IV. Command Store-and-Forward Schedule

The capabilities defined in this article are in the final stages of implementation. Plans are that these capabilities – with corresponding capabilities existing at the Mission Control Center – be available for the Voyager Mission in time to support the encounter with Jupiter. On approximately May 15, 1978, the Voyager Mission will begin test and training with this capability. Plans are that this capability will be operational in September 1978 to command the Voyager spacecrafts.

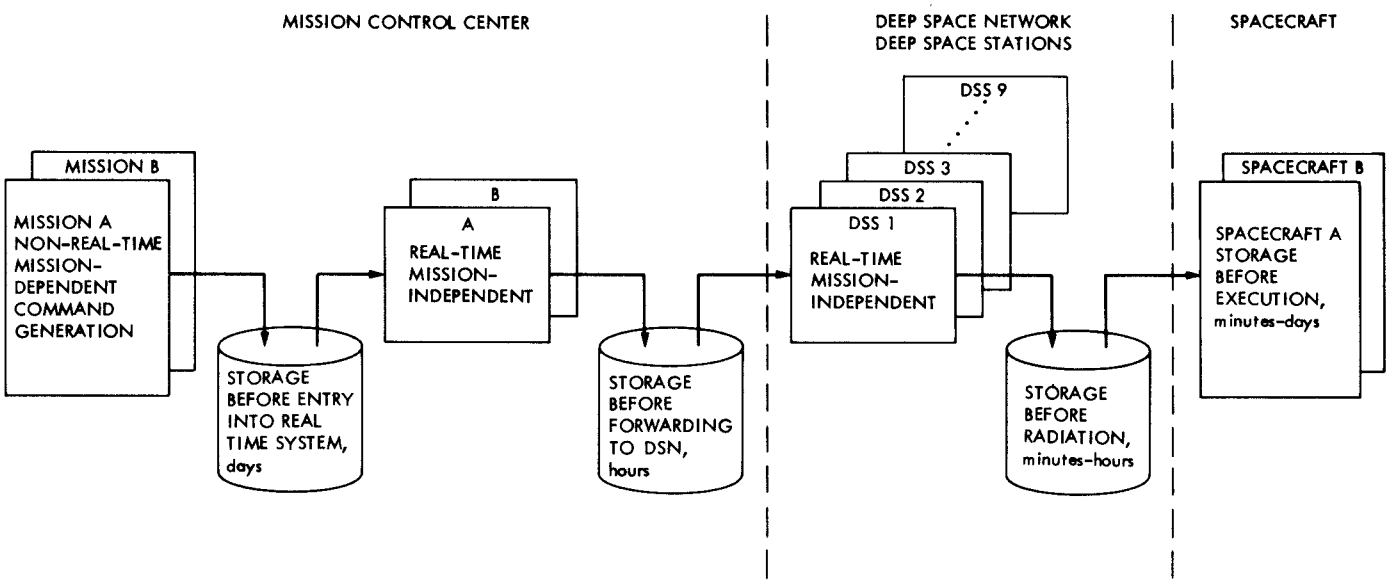

Fig. 1. Command store-and-forward general data flow – typical storage times